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WINDOWS AND LENSES USED WITH HIGH-POWER
CO_2 LASERS

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ANTIREFLECTIVE COATINGS FOR GaAs AND ZnSe WINDOWS AND LENSES USED WITH HIGH-POWER CO_2 LASERS

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Abstract: A kind of two—layer antireflective coatings for GaAs and ZnSe windows and lenses used with high power CO_2 lasers have been reported in this paper. Conparing with conventional quarfer—wave film stacks, they have properties of less absorption, wide band of antinflective wavelength nange and easy fabrication.

Key words: Antireflective coating, CO_2 laser

I. Introduction

ZnSe and GaAs optical components are components commonly used in high-power carbon dioxide laser devices. Almost all these components have antireflective coatings. Lenses and confocal nonsteady cavities have wholly-transparent exit windows. Antireflective coatings should be applied to the external surfaces for exit-coupled windows with a certain reflectivity; otherwise, parasitic oscillations are easily generated in the

cavity due to the reflections, thus affecting output laser beam quality.

Used for high-power carbon dioxide laser devices, the optical components have a decisive influence on absorption performance. With respect to thin optical films, the thicker the film, the higher the absorption. Therefore, the film thickness should be reduced as much as possible during design. There are very strict requirements on the refractivity of single-layer film in order to attain the properties of antireflective coatings. In other words, this is the square-root value of substrate refractivity. Such materials are very hard to find. Therefore, the thinnest possible antireflective film surface is the double-layer antireflective film system. As indicated in the computational results, the double-layer antireflective film is even thinner than the single-layer antireflective film with one-quarter-wavelength optical thickness. This kind of double-layer antireflective film system is the film system mainly discussed in this article.

II. Theoretical Design and Preparation of Double-layer Antireflective Film System

With respect to double-layer anti-reflective film system design, McLeod presented an analytical expression [1].

$$\tan^2\delta_1 = \frac{(\eta_3 - \eta_0)(\eta_2^2 - \eta_0\eta_3)\eta_1^2}{(\eta_1^2\eta_3 - \eta_0\eta_2^2)(\eta_0\eta_3 - \eta_1^2)}$$

$$\tan^2\delta_2 = \frac{(\eta_3 - \eta_0)(\eta_0\eta_3 - \eta_1^2)\eta_2^2}{(\eta_1^2\eta_3 - \eta_0\eta_2^2)(\eta_2^2 - \eta_0\eta_3)}$$

The equation contains η_0、η_1、η_2、η_3 , respectively, the

refractivities of air, first-layer film, second-layer film, and substrate. $\delta_1 = 2\pi\eta_1 d_1/\lambda, \delta_2 = 2\pi\eta_2 d_2/\lambda$ are, respectively, the phase thicknesses of the first and second-layer films. d_1 and d_2 are their geometrical thicknesses, and λ is the center wavelength. Here λ=10.6μm.

For solutions to the two foregoing equations, we must satisfy, either an all-positive, or two negative and one positive result in the following equations:

$$\eta_2^2 - \eta_0\eta_3$$

$$\eta_1^2\eta_3 - \eta_0\eta_2^2$$

$$\eta_0\eta_3 - \eta_1^2$$

Therefore, with respect to a certain substrate, an antireflective film can be formed by certain specific combinations of η_1 and η_2. This situation can be expressed with a Schuster diagram. Fig. 1 shows the Schuster diagrams for GaAs and ZnSe.

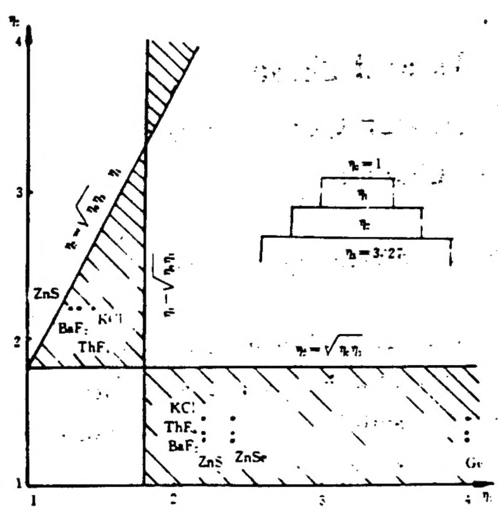

Fig. 1(A) Schuster diagram of GaAs substrate

In Fig. 1, the shaded zone indicates the zone with a solution. The dots stand for material pairs with a solution. As verified computationally, with respect to the dots in the lower shaded zone, the results obtained show thinner film layers and relatively stable performance. Considered only from the optics approach, the ThF_4/ZnSe pair is the best selection [2]. However, since ThF_4 is radioactive with its attendant complexity in coating, we selected the BaF_2/ZnSe material pair as the antireflective material for GaAs and ZnSe. Table 1 lists the calculated thicknesses of these materials. In the results, the values show a greater difference between the refractivity of BaF_2 and the values of the solid-state materials. This is due to taking into account the practical situation in thin-film coating process.

In the above-mentioned exact solutions, 100% transmissivity was obtained at 10.6μm, if we exclude the absorption and scattering by the material. However, this film system is not easily deposited because the optical thicknesses are irregular. However, we discovered, after careful study, that the optical thickness ratio is very close to integer ratios, therefore, we presented approximate solutions listed in Table 1. Although there are differences of +/-6.3% and +/-3.3% for the solutions of these two sets, and the exact solutions with respect to the optical thickness, however, they are still 99.95% and 99.99% of transmissivity at 10.6μm. This fact indicates that this film system is insensitive to thickness errors. Fig. 2 shows the

transmissivity curves near 10.6μm for the exact solution and for the approximate solution on the GaAs substrate.

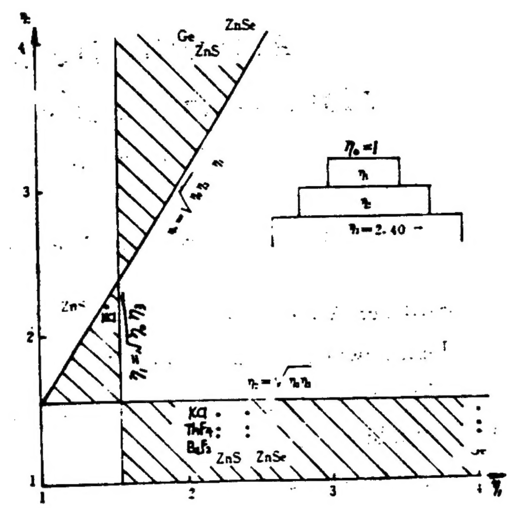

Fig. 1(B). Schuster diagram of ZnSe substrate

By using approximate solutions in the method with short wavelength monitoring long-wavelength film systems, in monitoring the film systems we can apply the polar value method. For example, with respect to the GaAs substrate, the monitoring wavelength can be selected as 1.930μm. Then the optical thicknesses of BaF_2 and ZnSe film layers are two polar values. Of course, chromatic dispersion of the material is a factor to be considered. However, the practical results prove that the effect of chromatic dispersion is slight. Fig. 3 presents the measured results of spectrophotometry for antireflective film on GaAs and

ZnSE substrates actually coated. At 0.6μm, the transmissivity T>/=99.5%. This film system was applied in optical components of high-power CO_2 laser devices, with ideal effects.

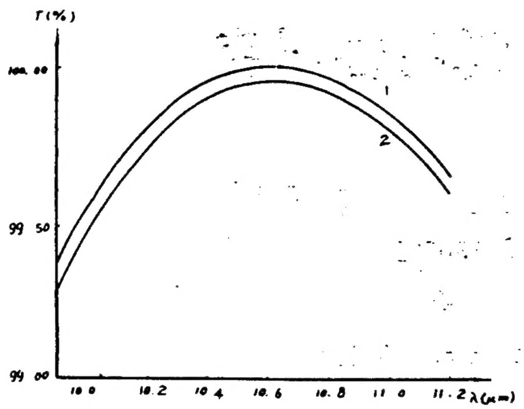

Fig. 2 Computed curves of transmissivity of double-layer antireflective film on GaAs substrate.
LEGEND: 1 - exact solution 2 - approximate solution

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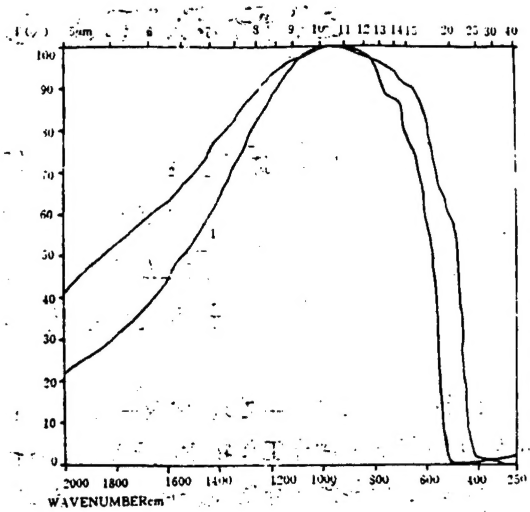

Fig. 3. Measured curves of transmissivity of antireflective film (flat lens, coated on both sides)
LEGEND: 1 - GaAs substrate 2 - ZnSe substrate

TABLE 1. Calculated Results of Thickness and Transmissivity of Double-layer Antireflective Film System for Substrate ¦BaF_2¦ZnSe¦Air on GaAs and ZnSe substrates

1 材料	2 折射率	GaAs 基片(η_3=3.27) 3				ZnSe 基片(η_3=3.40) 3			
		精确解 4		近似解 5		精确解 4		近似解 5	
		6 光学厚度 ($\eta_i d_i$)	7 透过率 T	6 光学厚度 ($\eta_i d_i$)	7 透过率 T	6 光学厚度 ($\eta_i d_i$)	7 透过率 T	6 光学厚度 ($\eta_i d_i$)	7 透过率 T
ZnSe(η_1)	2.40	1.025 μm	100%	0.965 μm	99.95%	0.605 μm	100%	0.625 μm	99.99%
BaF_2(η_2)	1.30	0.904 μm		0.965 μm		1.291 μm		0.625×2 μm	

KEY: 1 - material 2 - refractivity 3 - substrate 4 - exact solution 5 - approximate solution 6 - optical thickness 7 - transmissivity

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